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(54) **Title:** WIRELESS DETUNING OF A RESONANT CIRCUIT IN AN MR IMAGING SYSTEM

(57) **Abstract:** A device (30) for use with an MR imaging system (10) emits radio-frequency signals within a first range when acquiring data. A resonant circuit (50) within the device includes a plurality of electrical components (52, 54). An opto-electronic component (56) within the device electrically communicates with the resonant circuit. The opto-electronic component (56) is controlled to operate in a plurality of modes. The electrical components are not sensitive to the radio-frequency signals within the first range when the opto-electronic component (56) is operating in one of the modes.

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WIRELESS DETUNING OF A RESONANT CIRCUIT IN AN MR IMAGING SYSTEM

This application claims the benefit of U.S. Provisional Application No. 60/193,125, filed March 30, 2000, which is hereby incorporated herein by reference.

Background of the Invention

The present invention relates in general to nuclear magnetic resonance, and in particular to magnetic resonance (MR) imaging. It finds particular application in conjunction with detuning electrical components, which are sensitive to radio-frequency (RF) signals, within a catheter during an MR procedure and will be described with particular reference thereto. It will be appreciated, however, that the invention is also amenable to other applications in NMR and MRI, including those that are not specifically catheter based.

In interventional MR guided procedures, reliable and accurate visualization of instruments inside the body is essential for procedure success. Current methods for active device tracking involve the use of either single or multiple tuned RF microcoils integrated into the tip of a catheter to provide device position and/or orientation. These microcoils are connected to the MR system through the use of electrical wires (capacitive coupling), which often may also serve both detuning and signal transduction purposes. Separate leads are usually required for individual microcoil detuning and identification. This leads to a cumbersome design in which a multitude of leads may be required for an interventional device and in which patient safety may be compromised due to the potential to establish standing waves, high electric fields on the leads used for detuning, and hence patient tissue heating which is to be avoided.

In MR imaging (MRI) procedures in which tuned local coils are used for signal reception, detuning is also necessary to prevent high voltages from being induced in the receiving coil. These potentially high voltages pose a patient safety hazard (e.g., tissue heating from the RF energy deposited by a MR scanner) and the associated currents will create magnetic fields which disrupt the desired uniform radio-frequency excitation in the patient.

Conventionally, detuning is achieved by applying a voltage to a special portion of the electronics of the receiver coil. The introduction of such a voltage, which requires additional components to be integrated into the circuit, causes the receiver coils sensitivity or resonant frequency to change. In classic active catheter device tracking implementations in interventional MRI (IMRI), active leads, which are used for signal detection and coil detuning, extend the entire length of the catheter to couple the microcoils to an MR scanner. Induced electromagnetic field (EMF) signals from the microcoils are transmitted via insulated wires that are either embedded in the catheter wall or traverse the lumen of the catheter. If careful consideration is not undertaken during the design and placement of these signal wires, there is a possibility of signal corruption from either mutual inductance or stray capacitance. In tracking one or more microcoils, it is necessary to detune all but the coil of interest so that its position may be accurately ascertained without signal interference from the other coils.

Current techniques for detuning coils and coil switching in single or multiple coil systems require the use of additional components such as electrical leads to conduct biasing voltages to active electrical components, which require direct current (DC) voltages to be biased into operation. Alternatively, these biasing voltages can open or close diodes which add or remove inductors or capacitors from the circuit, thereby altering the resonant frequency of the coil. With the addition of these active components, wires for detuning coils and/or coil switching are required. These wires can compromise patient safety by introducing the hazard of electric shock if the device fails during the interventional procedures. Signal wires that extend through the catheter may also act as antennas, converting RF pulses from the MR system into heat and presenting a possible burn hazard.

In addition to signal purity and patient safety concerns, the design of an active, multiple coil system complicates catheter design and construction. For example, physical limits such as the size of the catheter and the number of signal/detuning wires that can be integrated within the lumen of the catheter must be considered. Constraints such as these ultimately limit the number of tracking coils that may be implemented on a catheter.

Prior art in the field of active catheter tracking includes the development and analysis of several different coil designs (e.g., single loop, carrier return, crossed loop and solenoid). The single loop and crossed loop coils have been shown to provide the best signal but worst distortion when oriented parallel to the main magnetic field. Center return coils produce the narrowest linewidth, but have low peak signal. The solenoid coil design does not perform well when oriented parallel to the main magnetic field, but provides the best signal when oriented perpendicular to the main field. In these studies, no detuning methods were employed during the imaging procedure. As discussed above, burn hazards from local heating caused by current flowing in the coil are possible and disruption of the typically desired uniform excitation field will occur.

Another conventional method provides small, untuned single loop integral RF coils that have sensitivities to signals within the radius of the coil (often about 1 mm) and use Hadamard multiplexed pulse sequences to determine location. The problem with this method is that tracking is possible only if a signal is stronger than the background noise level. In addition, if the axis of the receive coil is parallel to the main magnetic field, no current will be induced in the coil and tracking is not possible. One final deficit of the system is that signal loss can occur in regions devoid of MR-active material. Furthermore, no detuning methods are provided.

Another conventional method provides untuned, miniature solenoidal RF coils tuned into tips of catheters. These coils provide the ability to track catheter position and orientation, but employ multiple receiver channels for tracking multiple coils. However, no detuning methods have been employed.

Another conventional method provides tracking coils with internal Gd-DTPA sources. With an internal source, SNR is increased and tracking becomes possible in free space. However, no detuning methods have been implemented.

Another conventional method provides active tip tracking by the use of a thin copper wire wrapped around a catheter and connected to a battery. When current is switched on, a local field inhomogeneity is induced which causes a signal loss. However, issues regarding the electrical safety of actively introducing current into a patient are evident, and precise point-like localization of the device is not possible.

The present invention provides a new and improved apparatus and method that overcomes the above-referenced problems and others.

Summary of the Invention

An interventional device for use with an MR imaging system emits radio-frequency signals within a first range when acquiring data. A resonant circuit within the interventional device includes a plurality of electrical components. An opto-electronic component within the interventional device electrically communicates with the resonant circuit. The opto-electronic component is controlled to operate in a plurality of modes. The electrical components are not sensitive to the radio-frequency signals within the first range when the opto-electronic component is operating in one of the modes.

In accordance with one aspect of the invention, the means for controlling the opto-electronic component includes a PIN photodiode.

In accordance with another aspect of the invention, the means for controlling the opto-electronic component includes at least one of a photo-resistor and a photocell.

In accordance with another aspect of the invention, the electrical components in the resonant circuit are electrically connected in parallel.

In accordance with another aspect of the invention, the electrical components in the resonant circuit are electrically connected in series.

In accordance with another aspect of the invention, the means for controlling the opto-electronic component includes a fiber which transmits optical signals.

In accordance with another aspect of the invention, when the opto-electronic component is not operating in the one of the plurality of the modes, the electrical components may be sensitive to the radio-frequency signals within the first range. Also, when the opto-electronic component is operating in the one of the plurality of the modes, the respective ranges of radio-frequency signals to which the electrical components are sensitive are shifted to be outside the first range.

In accordance with another aspect of the invention, when the opto-electronic component is not operating in the one of the plurality of the modes, the electrical components are sensitive to radio-frequency signals, which may be within the first range. Also, when the opto-electronic component is operating in the one of the plurality of the modes, the electrical components are not sensitive to substantially any radio-frequency signals.

In accordance with another aspect of the invention, a second resonant circuit includes a plurality of second electrical components. A second opto-electronic component electrically communicates with the second resonant circuit. The second opto-electronic component is controlled to operate in a plurality of modes. The second electrical components are being sensitive to the radio-frequency signals within the first range when the second opto-electronic component is operating in one of the modes.

In accordance with a more limited aspect of the invention, the interventional device is tracked using time multiplexing.

One advantage of the present invention is that it eliminates the use of electrical detuning leads and, therefore, improves patient safety during interventional MR procedures that selectively track one or catheter-mounted coils which are either inductively coupled or capacitively coupled to the MRI system.

Another advantage of the present invention is that it utilizes a simple but effective circuit, which utilizes an optical scheme, for coil detuning.

Another advantage of the present invention is that it enables detuning for single coil systems without using additional conductive leads.

Another advantage of the present invention is that it may use inductive coupling, which requires no electrical connections for signal reception for tracking signals from microcoils.

Another advantage of the present invention is that it enables localization of each of a plurality of catheter mounted receive coils without requiring complicated active switching circuits.

Still further advantages of the present invention will become apparent to those of ordinary skill in the art upon reading and understanding the following detailed description of the preferred embodiments.

Brief Description of the Drawings

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating a preferred embodiment and are not to be construed as limiting the invention.

FIGURE 1 illustrates an interventional device of the present invention within an MR environment;

FIGURE 2 illustrates a first embodiment of the interventional device;

FIGURE 3 illustrates an electric circuit representation according to the first embodiment of the present invention;

FIGURE 4 illustrates a resonant frequency of an LC circuit when the photo-resistor is not exposed to light;

FIGURE 5 illustrates the frequency of FIGURE 4 after application of light to the photo-resistor;

FIGURE 6 illustrates an electric circuit representation according to a second embodiment of the present invention;

FIGURE 7 illustrates a varactor voltage-capacitance curve;

FIGURE 8 illustrates another embodiment of the interventional device;

FIGURE 9 illustrates an electric circuit representation according to the embodiment illustrated in FIGURE 8; and

FIGURE 10 illustrates curves showing time multiplexing according to the present invention.

Detailed Description of the Preferred Embodiments

With reference to FIGURE 1, an MRI system **10** includes a housing **12** around a horizontal bore **14**, which substantially surrounds a region of interest **16** including a support table **18** on which a subject **20** is positioned. A magnet **22** and a set of magnetic field gradient coils **24**, which substantially surround the support table **18** and the subject **20**, are included in the housing **12**. The gradient coils **24** create magnetic field gradients having predetermined strengths, in three mutually orthogonal directions, at predetermined times. A plurality of external coils **26** (only one is shown in FIGURE 1) also surround the region of interest **16**. The external coils **26** emit a range of radio-frequency (RF) energies (including, for example, about 8.25-85 MHz depending on the field strength of the magnet) into the region of interest **16** and the subject **20** at predetermined times and with sufficient power at a predetermined frequency so as to create an induced signal from nuclear magnetic spins within the subject **20** in a fashion well known to those skilled in the art. The spins resonate at the Larmor frequency, which is directly proportional to the strength of the magnetic field experienced by the spin. This field strength is the sum of the static magnetic field generated by the magnet **22** and the local field generated by the magnetic field gradient coil **24**.

FIGURE 1 shows one embodiment of an external coil **26** which has a diameter sufficient to encompass the entire subject **20**. Other geometries such as smaller external coils (e.g., surface coils) specifically designed for imaging the head or an extremity are also contemplated. The technology described here is applicable to such coils. In our embodiment, we implemented this on coils mounted on catheters that are to be inserted into the subject (interventional coils).

A device **30**, which is described in more detail below, is inserted by an operator **32** into a portion of the subject **20** located within the bore **14** (i.e., within a bore of the magnet **22**). In the preferred embodiment, the device **30** is a catheter. However, other embodiments in which the device **30** is a guide wire, an endoscope, a laparoscope, a biopsy needle, an external receive coil, etc. are also contemplated.

A processing (computing) device **34** acts as an operator interface for controlling the support table **18**, the magnet **22**, the magnetic field gradient coils **24**, the external coils **26**, and the device **30** via one (1) or more input/output devices including, for example, a keyboard **36**, a pointing device **38** (e.g., a mouse), and a viewing device **40** (e.g., a monitor having an optional touch-screen). As will be discussed in more detail below, the operator interface **34** receives data from the magnet **22**, the magnetic field gradient coils **24**, the external coils **26**, and the device **30** for providing an image of a position of the device **30** relative to the subject **20**.

With reference to FIGURES 1-3, the device **30** contains a resonant circuit **50**, which includes a plurality of electrical components. In the preferred embodiment, the resonant circuit **50** is formed from a capacitor (C) **52** and an inductor (L) **54** and has a resonant frequency defined according to:

$$\frac{1}{\sqrt{LC}}.$$

The device **50** also includes an opto-electronic component **56**, which electrically communicates with the resonant circuit **50**. The opto-electronic component **56** operates in a plurality of modes (e.g., preferably two (2) modes). For example, in a first one of the modes, the opto-electronic component **56** presents a high (e.g.,. above about 1 MΩ) resistance (i.e., an open-circuit) as sensed by the resonant circuit **50**; in a second one of the modes, the opto-electronic component **56** presents substantially zero (0) resistance (e.g., about 34.8 Ω with one device currently on the market) (i.e., nearly a short-circuit) as sensed by the resonant circuit **50**.

A fiber optic cable **60** included within the device **30** communicates with the opto-electronic component **56** and the operator interface **34**. By transmitting or not transmitting light to the opto-electronic component **56**, the fiber optic cable **60** acts as a means for controlling the mode in which the opto-electronic component **56** operates. Light is transmitted to the opto-electronic component **56** via the fiber optic cable **60** according to control commands initiated within the computing device **34**.

In the embodiment shown in FIGURE 3, the opto-electronic device **56** is a photo-resistor electrically connected in parallel with the capacitor **52** and the inductor **54** of the resonant circuit **50**. When no light is being transmitted to the opto-electronic device **56** via the fiber optic cable **60**, the photo-resistor **56** operates in the first mode and the resistance of the photo-resistor **56** is high enough (e.g., about 1 MΩ) such that the resonant circuit **50** senses an open-circuit across the points **62, 64**. Therefore, the inductor and capacitor resonant circuit **50** is sensitive to the range of RF signals emitted by the magnet **22** or the spins, and the MRI signal frequencies induced by the magnetic field gradient coils **24**, and the external coils **26**. Consequently, the parallel resonant circuit **50** inductively couples with the external coil **26**, which also acts as a receiving coil. However, when light is transmitted to the opto-electronic device **56** via the fiber optic cable **60**, the photo-resistor **56** operates in the second mode and the resistance of the photo-resistor **56** is low enough (e.g., about 34.8 Ω) such that the resonant circuit **50** senses nearly a short-circuit across the points **62, 64**. The short circuit changes the sensitivity of RF signals to which the electric components of the resonant circuit **50** are sensitive. More specifically, the short circuit across **62, 64** causes the electrical components (i.e., the inductor **54** and the capacitor **52**) to not be sensitive to the range of RF signals emitted by the magnet **22** or the subject spins, the magnetic field gradient coils **24**, and the external coils **26**. In other words, the electrical components are detuned and, consequently, are not sensitive to the MR RF frequencies and hence do not inductively couple a significant signal to external coil **26**. In Figure 3, the coil detuning and MRI signal induction is done wirelessly (i.e., without direct electrical connection) between the catheter coils and the MR system.

With reference again to FIGURES 1 and 2, in the scenario where signal reception is performed via direct (capacitive) coupling with the computing device **34**, although the inductor **54** and capacitor **52** is detuned via light signals transmitted along the fiber optic cable **60** to the photo-resistor **56**, RF signals are transmitted along electrical wires **66** from the resonant circuit **50** to the computing device **34**. The electrical wires **66** are subject to standing waves created by the RF signals and, therefore, pose the same safety risks to the subject **20** as those discussed above for the resonant circuit **50** within the device **30**. Therefore, additional opto-electronic components **68, 70** are electrically connected at positions along the wires **66** for changing the electrical lengths of the wires **66** as necessary. When activated, the additional opto-electronic components **68, 70** "cut" the electrical length of the wires **66** to a length such that the wires are not sensitive to the range of RF signals produced by the magnet **22**, the magnetic field gradient coils **24**, and the external coils **26**. In this manner, the safety risks associated with the wires **66**, which extend inside the subject **20**, are significantly reduced. In Figure 2, detuning is performed without wires; existing wires used for signal transduction to the MRI system can be "cut" to reduce their length and avoid heating issues via opto-electronic devices. During signal reception, the direct electrical connection is restored through control of the light signal from the user interface to the opto-electronic devices.

FIGURE 4 shows a peak depicting the resonant frequency **72** of an LC circuit (see, for example, the circuit **50**) when the photo-resistor **56** is not exposed to light. FIGURE 5 shows that after application of light to the photo-resistor **56**, the peak **72** of FIGURE 4 disappears and is replaced by a frequency plot illustrated as **74**. The frequency plot without a resonant peak **74** indicates the corresponding circuit is detuned.

A second embodiment of the present invention is illustrated with reference to FIGURE 6. For convenience, components of the embodiment illustrated in FIGURE 6, which correspond to the respective components of the embodiment illustrated in FIGURE 3, are given numerical references greater by

one-hundred than the corresponding components in FIGURE 3. New components are designated by new numerals.

With reference to FIGURES 1, 2 and 6, the opto-electronic device **76** is a PIN photodiode electrically connected in series with a detuning capacitor **75** and connected in parallel with the capacitor **152** and the inductor **154** of the resonant circuit **150**. When no light is being transmitted to the opto-electronic device **76** via the fiber optic cable **60**, the PIN photodiode **76** operates in a first mode and the resistance of the PIN photodiode **76** is high enough such that the resonant circuit **150** senses an open-circuit across the points **78, 80**. Therefore, the inductor **154** within the resonant circuit **150** is sensitive to the range of RF signals emitted by the magnet **22**, the magnetic field gradient coils **24**, and the external coils **26**. However, when light is transmitted to the opto-electronic device **76** via the fiber optical cable **60**, the PIN photodiode **76** operates in a second mode and the resistance of the pin photodiode is low enough that it switches in the detuning capacitor **75** into the parallel resonant circuit **150**. By switching in the detuning capacitor **75** the resonant frequency of the parallel resonant circuit **150** is shifted and the circuit is no longer sensitive to the range of RF signals emitted by the magnet **22**, the magnetic field gradient coils **24**, and the external coils **26**. In other words, the parallel resonant circuit **150** is detuned.

Although the opto-electronic component **56** is illustrated as a photo-resistor or PIN photodiode electrically connected in parallel with a resonant circuit, various other types of electrical configurations (e.g., a photo-resistor or a PIN photodiode connected in series with a resonant circuit, etc.) and other types of opto-electronic devices (e.g., a photocell or a photovoltaic cell) are also contemplated.

A photovoltaic cell is a semiconductor that converts light to electric current. It is a specially constructed diode, usually made of silicon crystal. A voltage variable capacitor or varactor diode is used in conjunction with a photovoltaic cell. Because the capacitance of a varactor diode is proportional to the controlling voltage, the varactor diode can be used to fine tune the resonant frequency of the circuit, where the resonant frequency is given by:

$$\frac{1}{\sqrt{L(C_{fixed} + C_{variable})}}.$$

When a reverse voltage is applied to a PN junction, the holes in the p-region are attracted to the anode terminal and electrons in the n-region are attracted to the cathode terminal creating a region where there is little current. This region, the depletion region, is essentially devoid of carriers and behaves as the dielectric of a capacitor. The depletion region increases as reverse voltage across it increases; and since capacitance varies inversely as dielectric thickness, the junction capacitance will decrease as the voltage across the PN junction increases. So by varying the reverse voltage across a PN junction, the junction capacitance can be varied. This is shown in the typical varactor voltage-capacitance curve **82** of FIGURE 7.

The device is constructed such that the varactor diode is placed in parallel with the existing parallel resonant circuit. The varactor diode may also replace the existing capacitors of the circuit if conditions permit. The varactor diode is connected to the photovoltaic cell and generates the necessary voltages to vary the capacitance of the diode to allow for either fine-tuning of the resonant frequency or inducing a large frequency shift and this detuning the circuit. An optic fiber is used to deliver light to the photovoltaic cell. The light intensity is modulated to modulate the tuning voltage.

A third embodiment of the present invention is illustrated with reference to FIGURE 8. For convenience, components of the embodiment illustrated in FIGURE 8, which correspond to the respective components of the embodiment illustrated in FIGURE 3, are given numerical references greater by two-hundred than the corresponding components in FIGURE 3. New components are designated by new numerals.

With reference to FIGURE 8, the device **230** contains a plurality of resonant circuits **250, 84**, each of which includes a plurality of electrical components. Although FIGURE 8 only shows two resonant circuits, it is contemplated to have twenty or more. More specifically, the resonant circuit **250** is formed from an RF coil including a capacitor **252** and an inductor **254**; the

resonant circuit **84** is formed from an RF coil including a capacitor **86** and an inductor **88**. The inductor **88** acts as a winding within the RF coil **84**. The device **230** also includes two (2) opto-electronic components **256, 90**, each of which electrically communicates with the resonant circuit **250, 84**, respectively. As discussed above, the opto-electronic components **256, 84** preferably operate in two (2) modes. Respective fiber optic cables **260, 92** communicate with the devices **256, 90** and the computing device **34**.

With reference to FIGURES 1 and 8-10, the external coil **26** is capable of inductively coupling with the inductors **254, 88** in the device **230**. Because two resonant circuits are included in the device **230**, it is possible to also determine both the position and orientation of the device **230**, in addition to their possible use as imaging coils. (Since the device **30** of FIGURE 2 only includes a single inductor **54**, only the position of the device **30** may be determined.) Furthermore, if the interrogation of the parallel resonant circuits **250, 84** and the external coil **26** is time multiplexed, it is also possible to determine the direction (trajectory) of the device **230**. This coupling is modulated by detuning the coils independently.

Time multiplexing is controlled by the computing device **34**, which causes control signals (i.e., light) to be transmitted along the fiber optic cables **260, 92** to the opto-electric components **256, 90**. More specifically, the curves **94a, 94b, 94c, 94d** of FIGURE 10 show that the control signal (light) is transmitted along the fiber optic cable **260** to detune the inductive coil **254** during a first time period **96a**. During the first time period **96a**, the circuit, including the inductive coil **88** is active and, therefore, inductively couples with the external coil **26**. Then, the control signal (light) is transmitted along the fiber optic cable **92** to detune the resonant circuit, including the inductive coil **88** during a second time period **96b**. During the second time period **96b**, the resonant circuit, including the inductive coil **254** is active and, therefore, inductively couples with the inductive coil **26**. Alternatively, a single multi-element optical fiber could be used and light of different wavelengths used to select which optoelectric device is activated, provided the light wavelengths match that of the devices. Multiple methods to

change the wavelength sensitivity of the opto-electronic devices are known to those practicing in this field.

Once the position of the device **30** or the position and orientation of the device **230** is determined, a graphic symbol of the device **30, 230** is superimposed on a conventional MR diagnostic image via the viewing device **40**. A series of successive images including the superimposed device is used for tracking a path of the device **30, 230** in the subject **20** or generating an image from the device at its current position, or receiving a signal from which spectroscopic analysis can be performed.

The invention has been described with reference to the preferred embodiment. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

Having thus described the preferred embodiment, the invention is now claimed to be:

1. An device for use with an MR imaging system which detects and emits radio-frequency signals within a first range when acquiring data, the device comprising:

a resonant circuit including a plurality of electrical components;

an opto-electronic component electrically communicating with the resonant circuit; and

means for controlling the opto-electronic component to operate in a plurality of modes, the electrical components not being sensitive to the radio-frequency signals within the first range when the opto-electronic component is operating in one of the modes.

2. The device use with an MR imaging system as set forth in claim 1, wherein the opto-electronic component includes:

a PIN photodiode.

3. The device use with an MR imaging system as set forth in claim 1, wherein the opto-electronic component includes:

at least one of a photo-resistor and a photocell.

4. The device use with an MR imaging system as set forth in claim 1, wherein the electrical components in the resonant circuit are electrically connected in parallel.

5. The device use with an MR imaging system as set forth in claim 1, wherein the electrical components in the resonant circuit are electrically connected in series.

6. The device for use with an MR imaging system as set forth in claim 1, wherein the means for controlling the opto-electronic component includes:

a fiber which transmits optical signals.

7. The device for use with an MR imaging system as set forth in claim 1, wherein:

when the opto-electronic component is not operating in the one of the plurality of the modes, the electrical components may be sensitive to the radio-frequency signals within the first range;

when the opto-electronic component is operating in the one of the plurality of the modes, the respective ranges of radio-frequency signals to which the electrical components are sensitive are shifted to be outside the first range.

8. The device for use with an MR imaging system as set forth in claim 1, wherein:

when the opto-electronic component is not operating in the one of the plurality of the modes, the electrical components are sensitive to radio-frequency signals, which may be within the first range; and

when the opto-electronic component is operating in the one of the plurality of the modes, the electrical components are not sensitive to substantially any radio-frequency signals.

9. The device for use with an MR imaging system as set forth in claim 1, further including:

a second resonant circuit including a plurality of second electrical components;

a second opto-electronic component electrically communicating with the second resonant circuit; and

means for controlling the second opto-electronic component to operate in a plurality of modes, the second electrical components not being

sensitive to the radio-frequency signals within the first range when the second opto-electronic component is operating in one of the modes.

10. The device for use with an MR imaging system as set forth in claim 9, further including:

a time multiplexing means for one of tracking the device and selecting which one of the coils to use for signal reception.

11. A method of controlling an device for use with an MR imaging system which emits radio-frequency signals within a first range when acquiring data, the method comprising:

determining if it desirable to detune a resonant circuit within the device from the radio-frequency signals within the first range; and

if it desirable to detune the resonant circuit, controlling an opto-electronic component, which is within the device, to operate in a control mode causing electrical components within the resonant circuit to substantially not be sensitive to the radio-frequency signals within the first range.

12. The method of controlling an device as set forth in claim 11, wherein the controlling step includes:

transmitting a light signal to the opto-electronic component via a fiber optic within the device.

13. The method of controlling an device as set forth in claim 11, further including:

shifting a range of RF signals to which the resonant circuit is sensitive when the opto-electronic component operates in the control mode.

14. The method of controlling an device as set forth in claim 11, further including:

reducing the sensitivity of the resonant circuit to any RF signals.

15. The method of controlling an device as set forth in claim 11, further including:

determining if it desirable to detune a second resonant circuit within the device from the radio-frequency signals within the first range; and

if it desirable to detune the second resonant circuit, controlling a second opto-electronic component, which is within the device, to operate in a control mode causing second electrical components within the second resonant circuit to substantially not be sensitive to the radio-frequency signals within the first range.

16. The method of controlling an device as set forth in claim 15, further including:

one of tracking and selectively receiving the device within the MR imaging system via time multiplexing.

17. A system for detuning electrical components used within an MR environment, comprising:

a magnet for creating a magnetic field within an area of interest;

a plurality of gradient coils for creating magnetic field gradients in the area of interest;

a plurality of external coils for emitting a range of radio-frequency signals into the region of interest;

an device including a coil;

an opto-electronic component electrically communicating with the coil; and

means for toggling the opto-electronic component between causing the coil to be sensitive and not sensitive to the radio-frequency signals emitted by the external coil.

18. The system for detuning electrical components as set forth in claim 17, wherein the device includes:

a second coil;

a second opto-electronic component electrically communicating with the second coil; and

means for toggling the second opto-electronic component between causing the second coil to be sensitive and not sensitive to the radio-frequency signals emitted by the external coil.

19. The system for detuning electrical components as set forth in claim 18, further including:

means for one of tracking and selectively imaging from the device coils by alternately toggling the opto-electronic components for alternately causing the one of the coils to be sensitive to the radio-frequency signals while the other of the coils is not sensitive to the radio-frequency signals.

20. The system for detuning electrical components as set forth in claim 17, wherein the means for toggling includes:

a fiber optic cable capable of transmitting light to the opto-electric components.

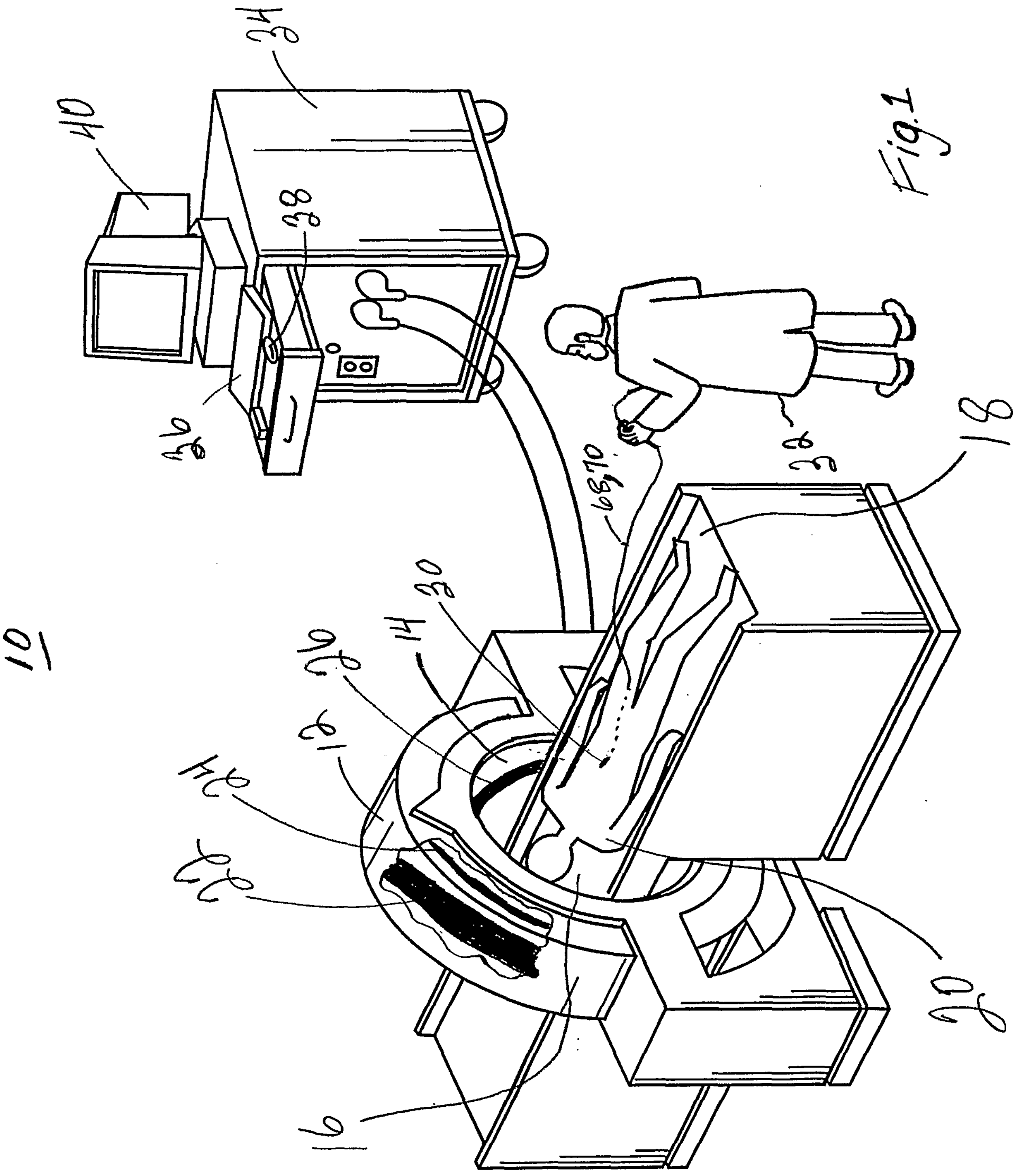

Fig.1

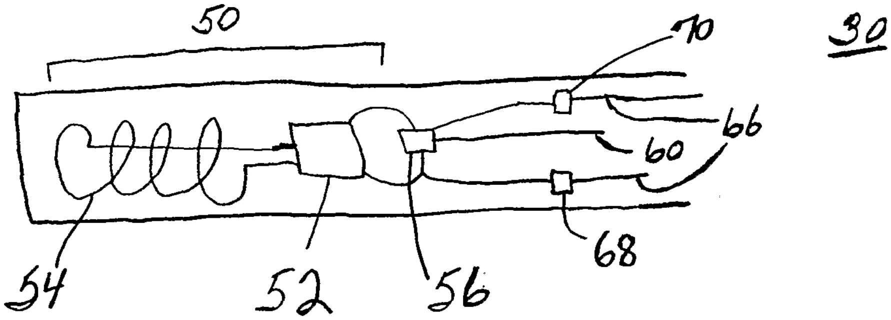

Fig. 2

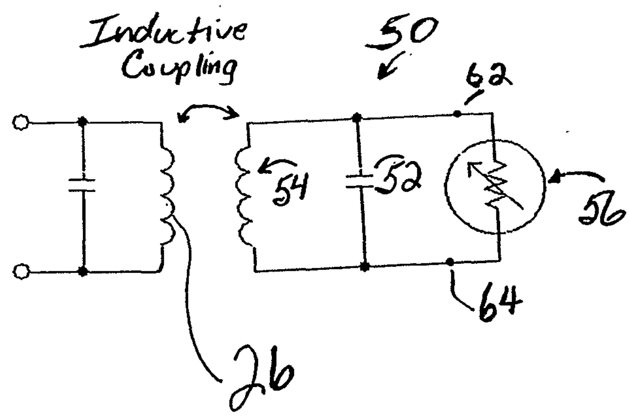

Fig. 3

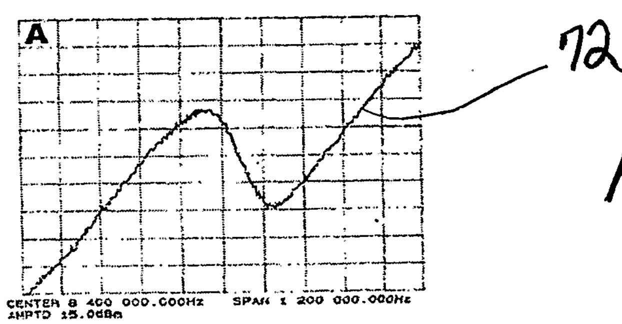

Fig. 4

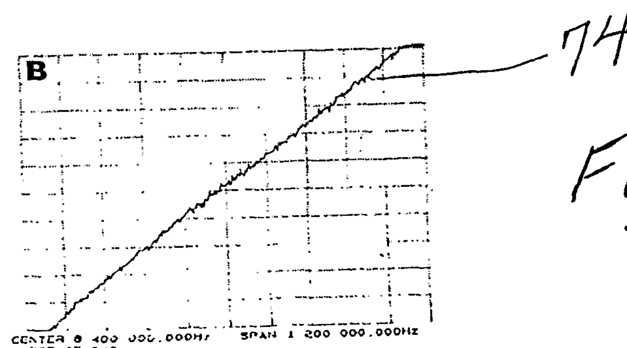

Fig. 5

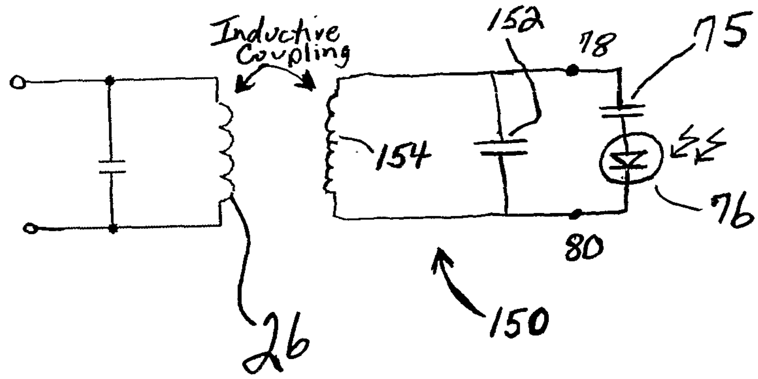
Inductive Coupling
152
78
75
154
76
80
150
26

Fig. 6

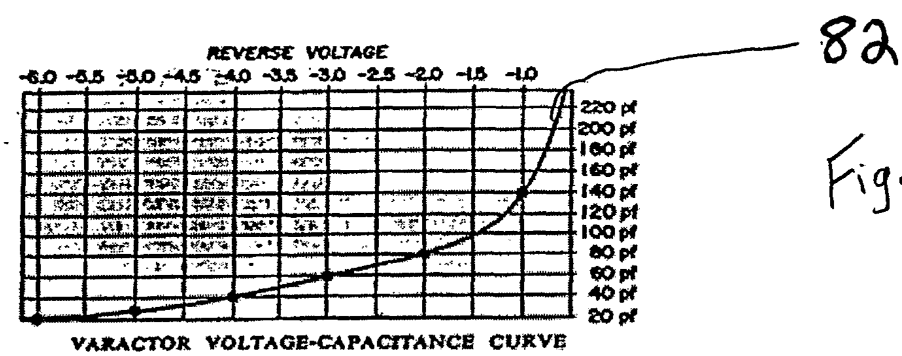
82
REVERSE VOLTAGE
-6.0 -5.5 -5.0 -4.5 -4.0 -3.5 -3.0 -2.5 -2.0 -1.5 -1.0
220 pf
200 pf
180 pf
160 pf
140 pf
120 pf
100 pf
80 pf
60 pf
40 pf
20 pf
VARACTOR VOLTAGE-CAPACITANCE CURVE

Fig. 7

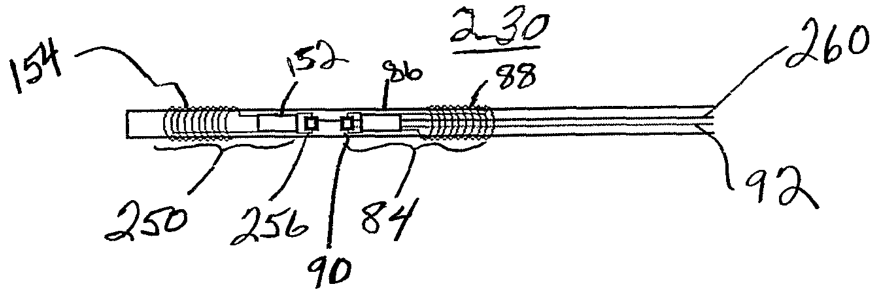

Fig. 8

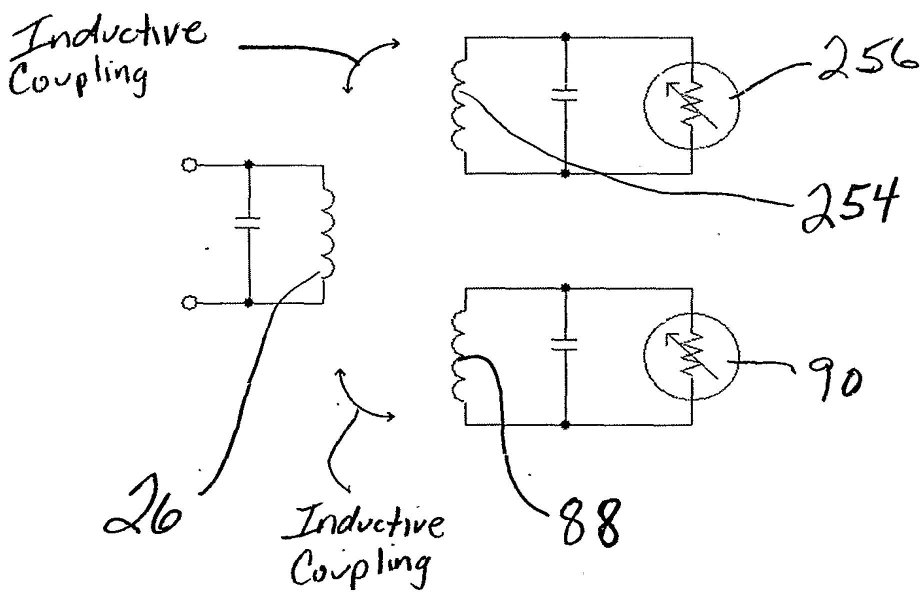

Fig. 9

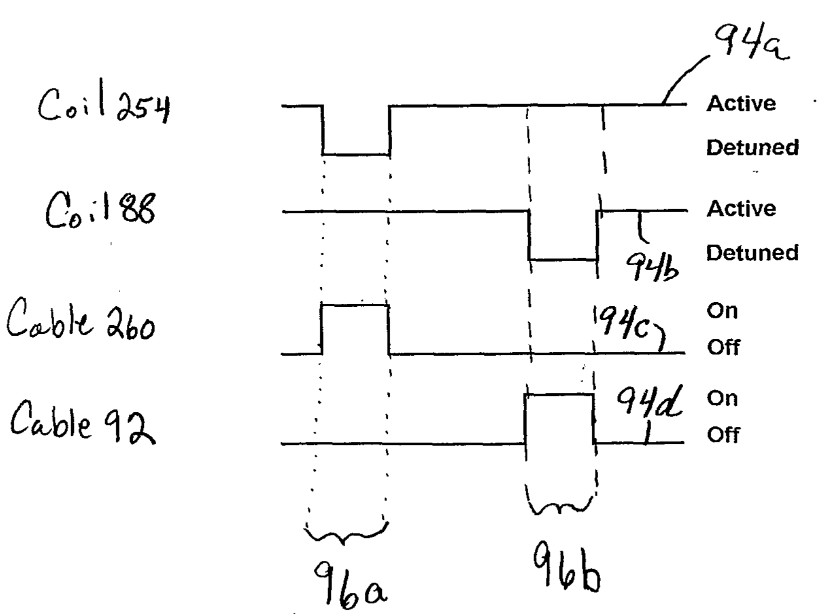

Fig. 10

INTERNATIONAL SEARCH REPORT

Int ıal Application No
PCT/US 01/10042

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01R33/28 G01R33/36 A61B5/055

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01R A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, MEDLINE, COMPENDEX, BIOSIS, INSPEC, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y		5

Y	WO 99 19739 A (BUSCH MARTIN ;MELZER ANDREAS (DE)) 22 April 1999 (1999-04-22) figure 2	5

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 August 2001	31/08/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Skalla, J

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
P,X	WONG E.Y. ET AL.: "An optical Technique for Detuning Parallel-Resonance Circuits in i-MRI Procedures" PROCEEDINGS OF THE INTERNATIONAL SOCIETY FOR MAGNETIC RESONANCE IN MEDICINE, EIGHTH SCIENTIFIC MEETING AND EXHIBITION, vol. 1, 1 April 2000 (2000-04-01), page 407 XP002170911 Denver, Colorado, USA * see the whole abstract *	1,3,4, 6-8, 11-13
A	US 5 318 025 A (DARROW ROBERT D ET AL) 7 June 1994 (1994-06-07) column 2, line 9 - line 45; figures 2A,2B,6	1-20
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